BRAZING AND SOLDERING

BY JAMES F. HOBART

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Brazing.

Soldering and brazing are terms often used to denote the same operation, that of joining similar or dissimilar metals by means of molten metal which may be of the same kind, but which usually has a lower melting point than the metals to be joined. The term "brazing" is usually employed to denote the soldering with an alloy of copper or zinc. "Soldering" is usually taken to represent the joining of surfaces by means of an alloy of lead and tin, and "hard-soldering" is understood to mean the process of uniting as above described with silver and its alloys used as a uniting metal. Hard soldering and brazing are practically the same, and are both done in about the same way.

The theory of brazing is the melting of a low fusing metal against the metals to be united while they are in such a condition of cleanliness and temperature that the metal welds itself to them. Soft brass, when melted, will weld itself to iron, copper, and a number of other metals, while the temperature of the metals in question is at a considerable number of degrees below their several melting points. In fact, only heat enough need be employed to fairly melt the uniting metal and to render it fluid enough to flow, or to "run," as the mechanic aptly states it.

To braze, also to solder, it is absolutely necessary that the surfaces to be united are clean and free from oxide.

The term "clean" is used in brazing and soldering, to mean that there is no "matter in the wrong place" as far as the surfaces to be operated upon are concerned. If the surfaces should be covered with a mixture of plumbago and soap, it is pretty sure that the brass would not adhere, and they could be called "dirty." If, on the contrary, the surfaces were daubed with grease, resin, lime, borax or similar substances, the brazing will not be interfered with; hence, it is better to say that surfaces to be brazed or soldered, should be made bright and free from oxide, finger marks, and all other matter except the proper flux to prevent oxidization of the surfaces when heated. This, and this alone, is the purpose of all the fluxes used either in soldering, brazing or welding. The flux prevents oxidization from contact of the hot metal with the air, or with the gases from the fuel used in heating.

Aside from the proper cleaning and fluxing of metals to be brazed or soldered, it is necessary that they be fitted together as closely as possible. It may seem like a paradox, but is the truth never the less, that when surfaces are united by brazing, the union is stronger the less brass there is between the surfaces. That is: The closer the fitting of the parts, the stronger will the braze be after completion. It is unnecessary to "leave space for the brass," in fitting for a brazed joint. The penetrating power of melted brass may be demonstrated by drilling a hole in a piece of iron or steel. Drive a plug in the drilled hole, and force it in as tightly as possible, then rivet the ends of the plug and proceed to braze around one end of it, when it will be found upon test, that no matter how tightly the plug may have been driven in, the melted brass has found its way through the plate beside and around the riveted plug, and that it has brazed both ends of the plug and its entire length as well. Therefore, fit tight, for brazing, and trust the liquid brass to find its way through the entire joint without fail.

Borax is the flux usually employed for all kinds of brazing. For commercial work on a large scale, boracic acid is used as it is cheaper than borax, being purchased in a granular form, in bulk, by the keg or barrel. For the uniting metal, some alloy of copper and zinc is universally employed. When other substances, such as silver is used, the operation becomes known as "hard soldering," as described elsewhere.

The particular alloy used for brazing, is called "spelter," and consists of equal parts of copper and zinc. For different operations it is necessary to use either a harder or softer alloy, hence the proportions of metals vary in the alloy according to the following table:

Brazing Alloys.	Tin.	Copper.	Zinc.	Antimony
Hardest,	0	3	1	0
Hard (spelter)	0	1	1	0
Soft,	1	4	3	0
Softest,	2	0	0	1

In a number of dictionaries, the proper metal for brazing is given as "Fine Brass, one part; Zinc, one part." This means that the copper in the brass receives another portion of zinc, thus making the alloy softer and lowering the melting point.

In commercial brazing, it is frequently profitable to mix the spelter with the proper proportion of boracic acid as found by experiment to be necessary. Then, the mixture is placed over or upon the parts to be brazed, and subjected to heat sufficient to melt the brass. As soon as the brass is seen to flow, "run," the workman calls it, the article is removed from the fire and the surface—if it will allow—is rubbed or scraped with a piece of metal or with a scratch brush to remove the flux and a portion of the superfluous brass. In many cases the scraping can not be permitted owing to the nature of the work, but whenever possible, it should be done as the flux comes off much easier when hot than after it gets cold.

The manner of applying the spelter and borax also differs with the work to be done. When a plain ring is to be brazed, it is sufficient to hang the ring on the end of a wire or a rod of iron and place a bit of spelter and borax inside the ring which has been placed so that the part to be brazed is downward. Usually the spelter and borax can be deposited in some angle of the work, or, upon some flat surface which will keep it in place during the heating operation. Sometimes, however, this is impossible, as in brazing a wire. In such cases, select a bit of spelter which is long enough to bend up U-shaped so it could be hung over the wire. The borax can readily be made to adhere by warming the wire.

It is best to heat rather slowly, in order that the joint may be brought to a dull red heat without burning any portion, or without any part remaining too cold. When the heat is forced so that one portion of the metal is hot enough to melt the spelter that happens to be on it, while another part of the joint is below the melting part of spelter, there is little possibility of securing a perfect joint. Heating evenly is absolutely necessary. It must be insisted upon or there will be no good work done in brazing.

Brazing can be done with any source of heat which will melt the spelter, but a properly arranged gas flame is the best that can be provided. The writer has more than once done work in an excellent manner in a pile of coals in an open fireplace with the hand-bellows as a source of air pressure. Indeed, upon one occasion, in a hunter's camp, a hatchet, split through the poll to the very eye, was successfully brazed with a bit of soft brass wire used for snaring fish. The flux was a bit of borax from the medicine chest, and the brass melting fire was a kettle full of coals set just inside the camp door and banked with wet clay to approximate a smith's forge. The necessary blast was supplied by a cone of birch bark, the large end of which was daubed with clay tightly into a hole in the wall of the camp. The small end of the cone led into a little clay passage which conducted the wind pressure into the bed of coals. No better working outfit could be desired for the limited work to be done.

When a smith's forge is to be used for brazing, use a charcoal fire, if possible. If bituminous coal must be used, coke enough of it to do the work, as the sulphur in the soft coal is not conducive to good brazing any more than it is to good welding, although a fair job of brazing may be done in an ordinary green coal fire by letting the coal remain without stirring while the brazing is being done.

If the work permits of being readily handled, make a sort of pit or crater in the pile of coal on the forge, and blow a few minutes until all the visible smoke and gas has ceased. Then lower the work carefully into the crater and blow very lightly, taking care that the spelter is in place and that it is not crowded away by the melting of the borax. Heat slowly and evenly, allowing the fire to lie without blast for short intervals. This permits the work to "soak" in the heat, as it is called by the workmen, resulting in very even heating of the work.

The workman should have at hand a small pointed rod or wire, with which to poke into place any bit of spelter which may shift its position and at the instant of melting, the spelter may be made to flow quickly and in the direction desired, by pressing the bits of spelter, one at a time, against the hot surface of the work. A row or group of spelter granules seem a good deal like sheep. Let one start to run, and all the others quickly follow. A bit of spelter forced against the hot metal receives its heat much quicker than when lying loose, and, as soon as one particle melts, it flows around the others, permitting them to receive heat and melt very quickly, hence the seeming following in the leadership of the first granule to melt. The work can be brazed at a considerable lower heat if a little care is taken to start the spelter a-flowing, as above noted.

In brazing in the smith's forge, it is well to hold the work "high up," that is, do not let it rest on the coal, but keep it suspended between the banks of incandescent fuel so that heat must reach all parts by radiation instead of a part by convection, as would be the case were the work to rest directly against the hot coals. When large work is to be handled, of course the above will not apply, and direct contact with the coal of the part to be brazed must be prevented by the work being supported at other places, leaving the working portion free and clear.

When considerable brazing is to be done, build a special furnace for that work alone, and, if possible, do the heating with gas. A blast of air will be necessary but a very small blower, similar to that used for a portable forge, will do all that is required. The diagram contained in Fig. 1, shows plainly the construction of a small home-made furnace for brazing. This furnace may be built up

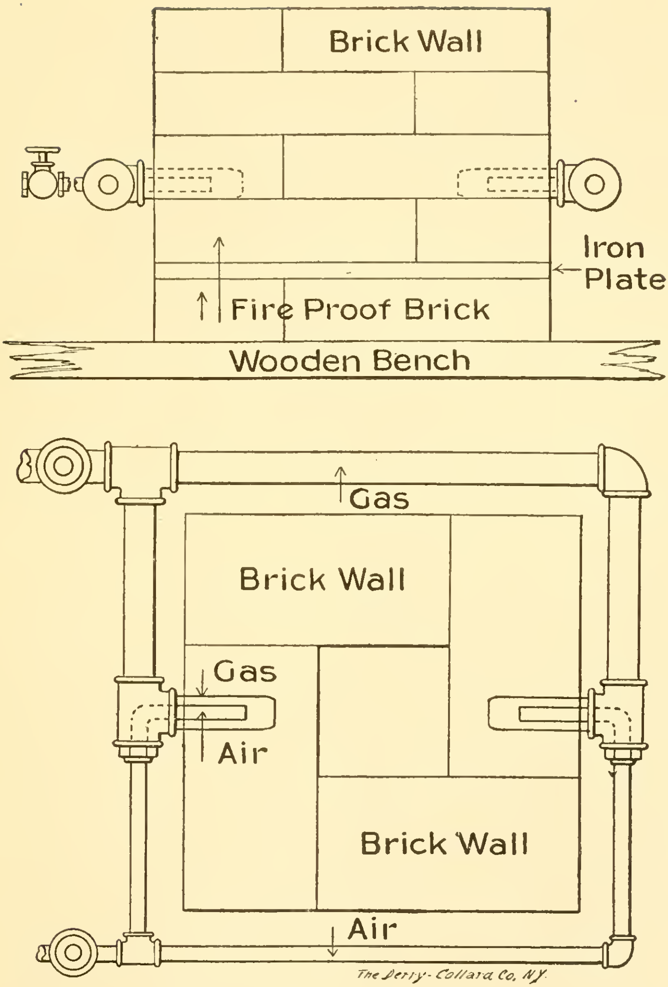


Fig. 1. Home made brazing furnace.

on a bench with loose bricks, or it may be constructed in a more permanent manner, using an iron shell with fire brick lining instead of loose bricks.

For bench use, there is an insulating layer of bricks laid upon the wood, then an iron plate and then the brick walls of the furnace are laid up. It is only necessary that the bricks are sufficient to hold the flame around the work to be brazed. There is a radiation or reflection of heat from a hot incandescent surface of brick or other material, like charcoal or carbon, which greatly aids in heating the object to be brazed. In fact, it is often impossible to braze certain work with the furnace at hand, until something has been placed around the work to keep the heat where it is needed—hence the use of the confined space in a brazing furnace, instead of letting the flame play directly against the work, in the open.

In Fig. 1, the arrangement of the gas and air pipes is shown. It is necessary that the air should be delivered inside of the jet of gas, as the air thus supplied inside the gas, together with the supply of air outside the jet, enables a much better and hotter flame to be maintained than when the air is delivered wholly around the gas instead of inside it. In the sketch, the two jets are shown controlled by a single valve, each for the air and the gas. Should there be trouble in obtaining the best results with either burner, it can be cured by putting a valve in each of the four pipes leading to the burners. Then it will be possible to adjust separately, the gas and air supply to each burner.

The entire piping may be made up of standard fittings, as shown by Fig. 1, or special castings and forgings may be provided, as desired. The size of the furnace may be made sufficient to take in the usual work to be brazed, bearing in mind that the smaller the furnace, the less gas will be required, and the more limited the work that can be done. On the other hand, while the large furnace costs more than the small one, and more piping and more gas is required to properly heat the apparatus, there is always the possibility of filling the large furnace with bricks to fit it to small work and the gas can always be cut down to fit the furnace by means of the valves provided for that purpose. It is in order, then, to provide as large a furnace as there is likelihood of there being work for, then fill up the fire-pot with fire bricks until economy of gas is secured for the particular work to be done. Then, when a large piece of work comes along, take out the bricks, and a large furnace is at hand. The above remarks, of course, apply to job and repair work. For special manufacturing where the same work is to be done day after day, there will, of course, be provided special brazing furnaces, fitted for the particular work in hand.

Cleaning work which is to be brazed, is a most important part of the operation. Usually, filing, scraping or grinding must be resorted to. Cleaning by means of acid is sometimes attempted, but this method sometimes proves very far from being satisfactory. If the surfaces are not thoroughly cleaned of grease by the use of strong alkali, the acid will fail to make the entire surface bright, and a poor braze will be the result. Again, if the acid be not entirely removed at the time of cleaning the surfaces, then there will be more trouble, for the acid remaining on the metal will proceed to unite with it into a film of oxide which will not only prevent a perfect braze, but which will probably cause an apparently perfect union to fall apart as the acid left in the metal gets in its work of undermining the layer of brass which has been put upon the work during the operation. Thus: Free acid causes the joint to "rust out"—something which is fatal to good or lasting work.

The apparatus described above is applicable for braz-

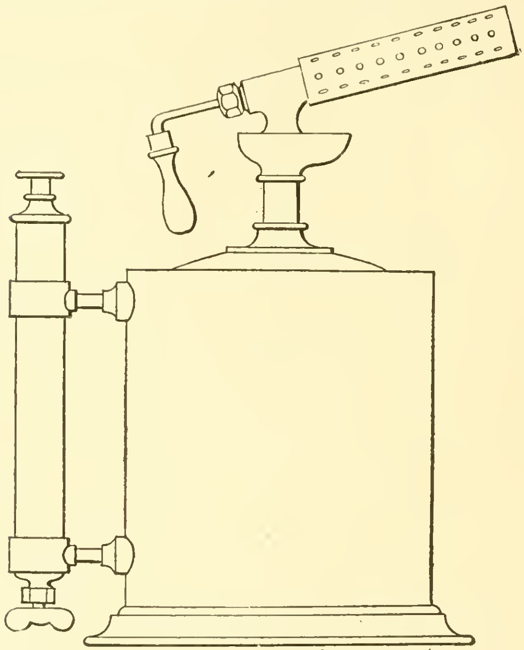


Fig. 2 Gasoline torch.

ing heavy work. For light brazing, a simple gasoline torch may be used, as shown by Fig. 2. This appliance gives a very strong flame, but if it be directed upon a piece of iron for an entire day, there would not be sufficient heat to make much of a piece of iron red-hot, to say nothing of melting the spelter. However, there is heat enough developed in the gasoline flame to make a considerable braze. All that is necessary, is to put the heat just where it is needed, and to hold it there. This is best done by building around the work with charcoal which becomes incandescent from the heat of the gasoline flame, and also sets up a heating scheme from its own combustion.

If the article to be brazed, be a very small one, it can be placed bodily in a hole scooped in a bit of charcoal, as

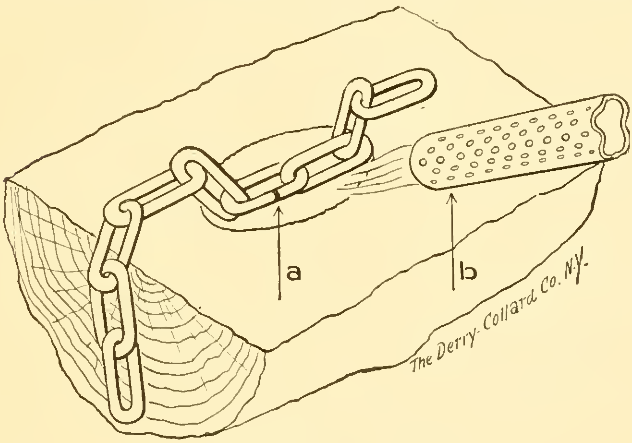


Fig. 3. Brazing in charcoal block.

shown by Fig. 3. Here is shown the brazing of a link in a small chain. The broken link is carefully wedged into the hole in the charcoal, and bits of coal may be packed around the link if the latter be comparatively large. The place where the link is to be brazed, is indicated at a, and the heat is applied from the torch b, which, of course, is applied at the most convenient angle.

Another very convenient method of applying charcoal in the brazing operation, is shown by Fig. 4. Here, the work is held between two pieces of hard charcoal which are clamped firmly upon the work. If the coal is in the way at first, the flame from the torch will quickly burn away the interfering parts. Two or more pieces of metal can be held firmly for brazing by this method, and the charcoal is also brought very close to the point of heating.

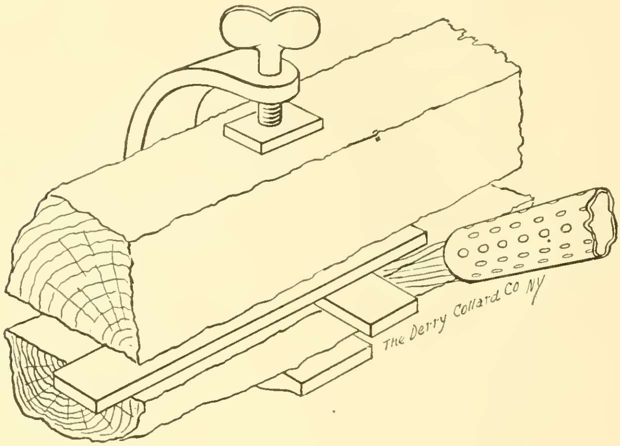


Fig. 4. Another way of using charcoal.

A very excellent device for brazing in a shop where there is considerable work, but no gas to do it with, consists of a pair of torch burners attached to a compressed air reservoir of considerable size, as indicated by Fig. 5. The action of this tool is the same as for the torch; it is pumped up after some gasoline has been put into the air-tank, then the burners are heated and ignited in the usual way, the necessary air pressure being pumped up in the tank by means of an ordinary bicycle pump—if no better way be rigged in the shop.

Pieces of fire brick, laid on either side of the path of the flames will confine them a great deal and if pieces of charcoal be placed inside of the bricks, a very high degree of heat can be obtained. Each torch-head is so arranged that it can be swivelled in any direction. If both torches be turned so they point nearly in the same direction, the

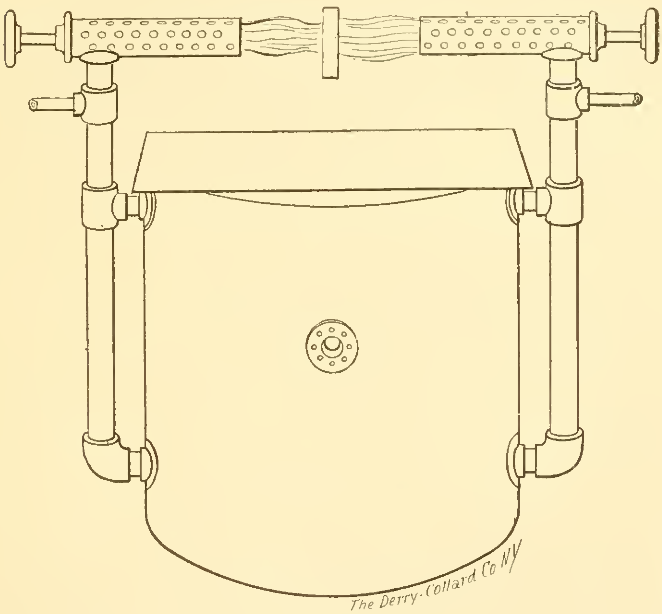


Fig. 5. A good brazing device.

flame from the two torches will form a sort of V, and at the point where the flames come together, is a very hot place. With a backing of fire brick and charcoal as above described, iron may almost be melted with this appliance.

Blow-pipe brazing is done in exactly the same manner as described for blow-torch work, only, as large work cannot be attempted as with the torch, simply for the reason that there is not as much heat developed with the small blow-pipe, as with the larger blow-torch. The intensity of the flame, however, is as great, and even much greater with the little blow-pipe than with the largest torch ever made.

There is an excellent tool for soldering and small brazing, which consists of two tubes, one for illuminating or hydrogen gas, the other tube for compressed air. These tubes are attached to flexible rubber tubes as shown by Fig. 6, one leading to the gas fixture, the other to a source

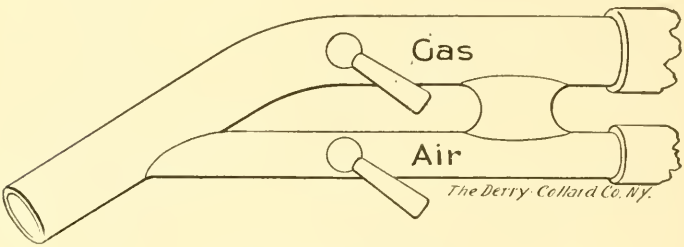


Fig. 6. A handy blow pipe.

of compressed air. On small work the air-tube is often held in the mouth and the air supplied by the operator. This blow-pipe may be attached to, and used in connection with the apparatus shown by Fig. 5. For work larger than the double blow-torch can handle, the air-gas blow-pipe will be found a very welcome addition to the source of heat.

Fig. 7 illustrates two types of blow-pipes ordinarily used. The ball on one of them, is hollow, and is supposed to render the flame a little hotter by catching the moisture that may be imparted to the air by being blown through the lungs and mouth. The chief benefit to be derived from the ball, is in catching whatever portions of saliva are blown into the tube with the air. The plain blow-pipe dispenses with the moisture catching device, and some of the best work is done with this kind of a blow-pipe.

Fig. 8 shows the manner of blow-pipe application to a small job of brazing. The work is held in a pair of

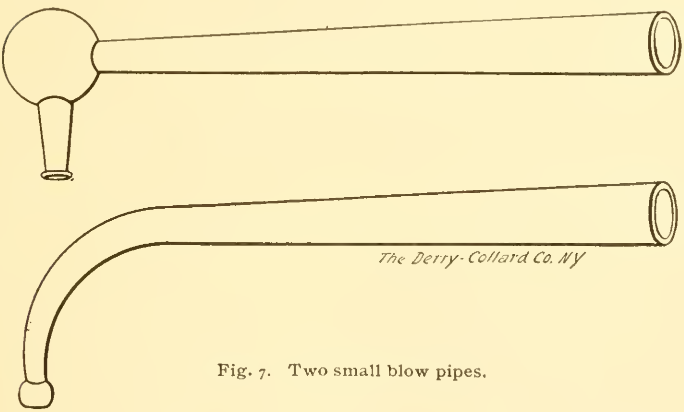


Fig. 7. Two small blow pipes.

tongs or pliers, between pieces of hard charcoal, and the flame of the alcohol lamp is diverged as shown, by the stream of air from the blow-pipe nozzle. For small brazing jobs, also for hard soldering, and for many kinds of soft-soldering, this apparatus is of inestimable value to the mechanic. The lamp is made with a spherical alcohol reservoir, which forms the body of the lamp, and it swings in any direction, in the metal base of the lamp. The flame may, therefore, be put in any position within the capacity of the lamp.

Brazing.

There has recently developed two new methods of brazing, which for manufacturing purposes, throw in the shade, all methods known before the advent of the two methods in question, one of which is known as "Brazing by Immersion," and consists of dipping the article to

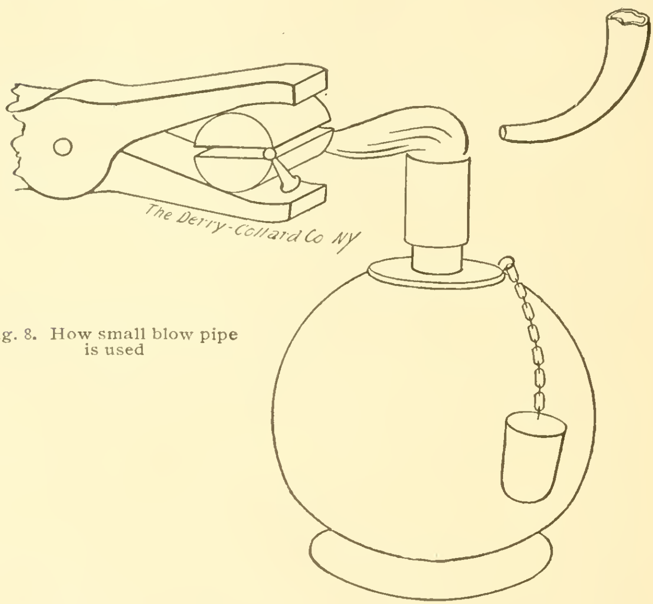


Fig. 8. How small blow pipe is used

be brazed, into a bath of melted spelter, on top of which is maintained a body of molten flux, through which the articles to be brazed have first to be passed. Fig. 9 shows one form of crucible or melting pot used to contain the fluid flux and spelter. Common round crucibles are also used, the only necessity being that the containing vessel must be large enough, and the melted metal high enough to allow of the parts to be brazed being immersed sufficiently to bring them entirely beneath the surface of the hot spelter. When the pot shown by Fig. 9 is used, large work is to be handled, therefore provision is made for a considerable body of molten metal, hence the long, flat pot, into which can be dipped almost any portion of an object which is not absolutely flat and longer than the pot.

The position of the work in the pot is pretty well shown by Fig. 10. The pot is shown upon a bed of coals, but it would be better if it were heated by a gas furnace.

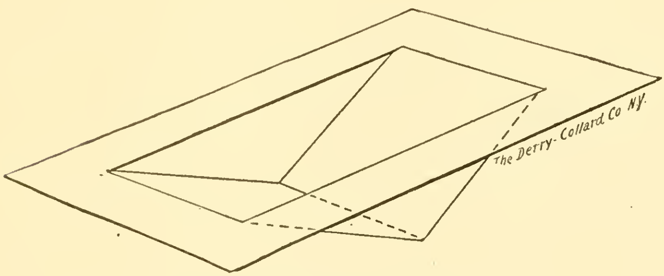


Fig. 9. Special crucible for immersion.

On top of the metal is the body of flux, a, in a molten state. The body of spelter, b, underneath the flux is also kept in a melted state, and when the object to be brazed is first introduced, it is held in the hot flux for a short time before it is put down into the spelter. The object of holding the work a while in the flux is two-fold. Not only is the object heated, but it is coated with a layer of flux which prevents oxidation. When thoroughly heated and coated with flux, the work is passed down into the spelter, which immediately attaches itself to the work, coating every part thereof and insinuating itself into every crack and corner. Between surfaces, capillary attraction fills all the space and makes a solid filling after the work has cooled.

In this kind of brazing, parts of the work which must not be adhered to by the spelter, are covered with graphite specially prepared for the purpose in such a manner that the brass will never adhere where the "anti-flux" graphite has been applied. This substance is made up into a paste

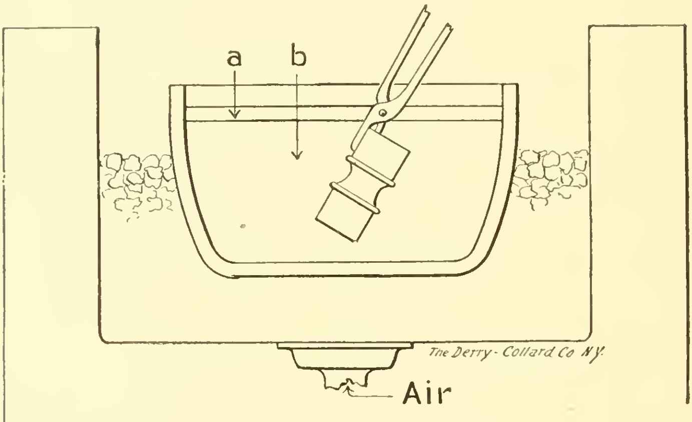


Fig. 10. Using a round crucible.

and applied with a brush to parts which must not be covered by the spelter. The graphite is not affected by the intense heat of the spelter, and if care is used in painting on the graphite, little or no filing will be necessary after the brazing operation has been finished.

The proper flux to use with one of these furnaces, is pretty hard to determine. Some operators use pure borax, and keep it from three-eighths of an inch, to over two inches deep on top of the spelter, while other people who do excellent brazing, use three parts boracic acid and one part borax, while others use exactly the opposite proportion of borax and acid. Other people use boracic acid straight, without anything else with it. Again, some use soda mixed with borax, and, in fact, almost any compound which has borax in it, seems to work well as a flux in the dipping process of brazing.

The other method of brazing, alluded to above, as being a great advance in the process of brazing, is known as the "Pich Process of Brazing Cast Iron." Cast iron can be brazed by the methods described above, but it is very delicate business, as the iron melts, or at least softens so it will break under the least strain, at a temperature pretty near that at which the spelter melts, so that it is almost impossible to melt the brass without "burning" up the cast iron which is being brazed.

By the Pich method, the surfaces to be brazed are first brushed over with a varnish made of oxide of copper mixed with any liquid which will allow of the copper being spread with a brush, and which will afterwards hold the oxide when dry.

After this application, the brazing is carried out the same as in the ordinary method. The brass or spelter is placed in position, and the flux applied, then a gas-air flame is applied as in ordinary brazing. It is assumed that the metallic oxide acts as a reducer on the surface of the cast iron to be brazed. Without the oxide, the carbon above noted acts much like the graphite used in the dipping method of brazing as an anti-flux as described in the description of the dipping process of brazing. It is claimed that the metallic oxide is reduced, removing during the process of reduction, the carbon on the surface of the metal, and, it is claimed, often penetrating for a distance of three or four inches into the metal itself, thereby making the cast iron stronger at and near the joint, than it was before. Of this matter, the writer has no personal knowledge. The process has been described very fully in a paper by Wilifred Lewis, read before the American Society of Mechanical Engineers.

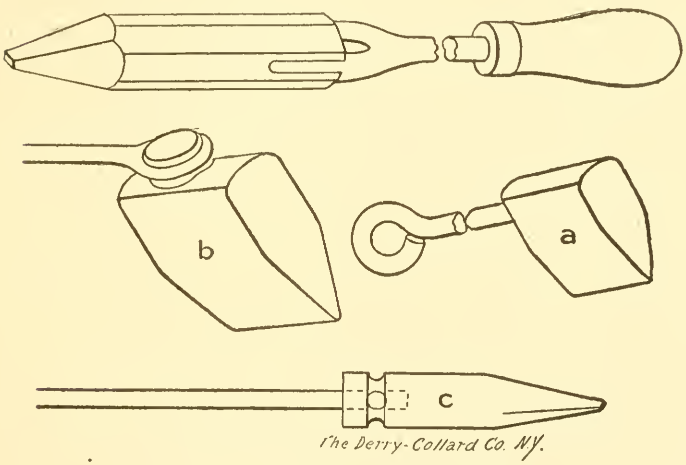
It is claimed that both the joint and the casting itself is made from 5% to 10% stronger by the treatment with oxide. This, if correct, is a pointer of value to the iron worker, aside from in the process of brazing, for, if in certain cases, cast iron can have its strength increased 10%, it will be of inestimable value to the designing engineer to know thereof.

Soldering.

Soldering is much like brazing in some of its details. In fact, some kinds of soldering are done exactly like some kinds of brazing, but other varieties of soldering are totally unlike any brazing operations. Soldering, therefore, may be taken to mean the uniting of two or more pieces of metal, with fusible alloys of lead and tin. Sometimes, lead areas are united by melting their surfaces without the use of solder, the surfaces being fluxed. This form of soldering differs slightly from welding, and is called "burning" by the trade. The method is usually employed in uniting the edges of sheets of lead used in the lining of acid tanks or similar apparatus.

The particular kind of soldering usually employed is by the use of the so-called "soldering iron," which is really a copper bit placed on the end of an iron handle.

An alloy of lead and tin is used which readily adheres to the surface of the bit, which must be clean, free from oxide, etc. The operation of coating a copper bit with solder is known as "tinning," and will be described elsewhere. The theory of soft soldering is: that as the soft metal adheres to, and unites with the surface of the copper bit, so will the soft metal, under certain conditions, ad-



Figs. 11 and 12. Forms of soldering "irons."

here to, and unite with the surface of the metals to be soldered. In fact, soft soldering, as well as brazing, consists of welding together two or more pieces of similar or dissimilar metals by means of another metal of lower melting point. That constitutes soldering; all the rest of the operation, is detail, which may be varied to suit conditions.

The form of copper bit usually employed, is shown by

Fig. 11, herewith. There are also many other shapes in common use, and those represented by a, b, c and d, in Fig. 11, are frequently seen. In the latter illustration, a is the "hatchet" bit, used perhaps more frequently than any of the others, except that shown by Fig. 11, which is the tool with which nearly all jobbing and repairing is done. The "hatchet" form of bit is also shown by b, Fig. 12, and differs only that the handle is swivelled so that the edge of the bit may be turned in any direction as made necessary by the work in hand. This tool is used for long, straight seams, and for heavy work generally. The bit shown at c, is one of the many shapes used for special work. Tools of any shape can be easily made by the workman who simply forges the copper when cold, to the size and shape desired. Copper forges on the anvil pretty well and if the precaution be taken to anneal the bit frequently, almost any desired shape can be made with little if any filing or cutting—simply by forging alone. The annealing operation for copper, consists of heating to a dull red heat, and then quenching in water—the reverse of the steel hardening operation.

The shape shown by C, is a very useful tool where soldering has to be done in corners or small places. It is of the same shape as form A, except that it is smaller, and round in section, instead of "hex." The handle is screwed into the bit, and three holes are drilled and tapped so that the handle can be put in as shown, or with the flat end either "hatchet," or "cross," as the work to be done may demand. The swivel hatchet bit, B, is one of the most useful tools. It ranks next to form A. Fitted with the two tools, Fig. 11, and B, Fig. 12, all kinds of large work can be done. With the addition of C, the stock is complete.

Even more important than the shape of the bits, is their condition. A man can do good work with any "plug" of a tool, as long as it is cleaned and well tinned. It is in this, that the life of the tool lies. With a poorly tinned tool, it is impossible to do good soldering. It is then, of the greatest importance that the user of soldering tools knows how to put them in shape and how to keep them there. To begin with, a bit can never remain in

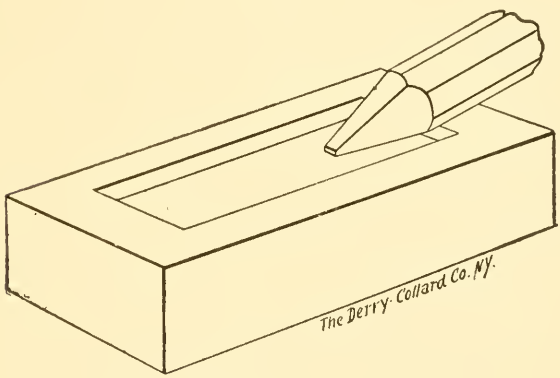


Fig. 13, Brick "jig" for tinning copper.

good condition if it is over-heated. Once a bit is made red-hot, its usefulness is gone until it has been re-tinned. Heating in a soft coal fire also causes the tinning to vanish very quickly.

In order to learn how best to keep a bit well tinned, it is necessary to learn how to tin the bit the first time. Renewing the tinning is practically the same as the first tinning. To tin a copper, see that it is of the shape required, then brighten the sides and edges of the point with a file. Heat the bit until it is barely hot enough to melt a little metal off a stick of solder when pressed against a bar of that alloy. If the bit is too hot, the tin cannot be made to adhere to it. Cool the bit on a wet rag, if it should be heated too hot, but, the sooner the beginner learns to "never let the coppers get too hot," the sooner he will be an expert at soldering.

Perhaps the best "jig" for tinning coppers, is a brick with the top cut out with a cold chisel, something as shown by Fig. 13. The softer the brick, the better "jig" it will make. A very hard burned brick will not let the copper rub off little bits, while a soft, pale yellow brick

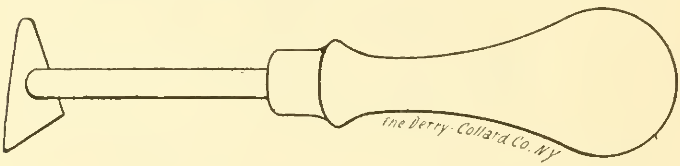


Fig. 14. A handy scraper.

rubs off like sand and the material thus removed, unites with the resin used in the operation, and helps to brighten the surface of the copper.

The cavity in the top surface of the brick may be made about an eighth of an inch deep, and some resin melted into it. Some pieces of salammoniac, scattered in with the resin, improves the working of the "jig" immensely. In fact, that substance is the natural flux for copper, and that metal may be soldered with no other flux except a little of the muriate of ammonia as the chemical in question is technically known. Some solder is melted into the cavity on top of the brick, and there mingles with the other material. The heated copper should be rubbed back and forth on the brick, amid the melted solder and flux. The particles of brick serve to brighten the copper so that the solder readily adheres, covering the entire point of the bit, as far back as it may have been brightened, or rubbed against the surface of the brick.

In using the copper give it a rub or two on the brick just before replacing to heat, and the copper will always keep well tinned. If, at any time, through over-heating or soldering dirty surfaces, the tinning begins to disappear, a few rubs on the brick will replace the tinning as good as new. When several coppers are in use, they are usually tinned by rubbing two bits together, taking one with either hand, and rubbing them together on the brick. Then, the brick brightens the coppers and the rubbing of the two together, causes the molten metal to adhere very quickly. Coppers may be tinned in many other ways. Simply rubbing the bit on the ground, or on the floor of the shop will brighten the metal, and the tinning may be proceeded with on a bit of tin, with nothing but resin and solder. But the brick "jig" is much the best—and quickest.

Overheating causes the copper to become rough and worn in spots. It often seems as if an acid had eaten into the copper in one or more places, but overheating is the sole cause of the trouble. Learn to judge quickly and correctly the degree of heat in the copper by holding the bit about one inch from the cheek. The radiation of heat is quickly felt, and in a very short time a man can learn in this way, to closely judge the amount of heat in the copper. The right heat has been attained when the solder flows like water when melted with the copper, on a bit of bright new tin plate. If the solder can be made to build or pile up in the least, the copper is too cold. If color shows on that portion of the copper which is covered with solder, then the bit is too hot. There is quite a range of temperature between the two extremes, and there all the work of soldering should be done.

Never try to solder when the tool is so cold that the solder will not run freely. Good work *cannot* be done with the copper in that condition. Heat when the solder shows the least trace of granular formation, and when it begins to "build up" under the copper, from the surface of the metal which is being soldered. If the tool be a trifle too hot, push it along the top of the brick "jig" a few times and the heat will be reduced and the tinning on the copper will be improved by the operation.

In soldering, the same rules apply regarding cleanliness, as in brazing. The surface must be free from dirt, oxide, or any foreign substance which will prevent the adherence of the solder. On old work, the surfaces must be brightened by scraping, filing or rubbing with sandpaper or emery cloth. Scraping is the best, and a useful tool for the purpose is shown by Fig. 14. This scraper may be bought from the same dealer who supplies soldering tools and supplies. This tool has a steel blade, which should be hardened and should be ground on the side not shown in the drawing. The corners of this tool are different from each other, one being pointed, the others rounded off on different radii.

Where scraping can not be done to advantage, filing may be resorted to; grinding may be done; emery cloth used, or the surface scraped bright with the blade of a knife. The scratch-brush may also be used, but the surfaces must be cleaned of oxide in some manner at any cost, or no good soldering can be done.

For all small work, the solder should be applied to the copper, instead of direct to the work. Fig. 15, illustrates the proper method of picking up solder with the bit. A bar of "half and half" is laid on the bench, one end being raised a trifle by having a bit of wood, a cold chisel, or some other small article placed under it. Touch the hot copper to the bar of solder, and a portion will melt and adhere to the copper. If the tool be held against the

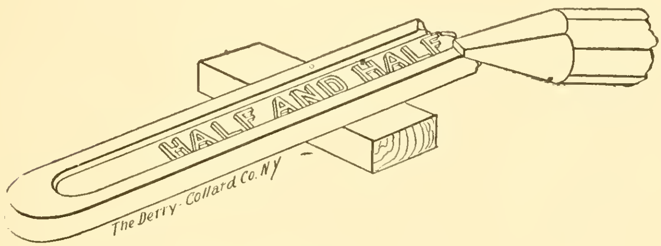


Fig. 15. Taking solder from bar.

solder too long, the solder will run down upon the bench. Only a very small portion of the metal can be taken up at one time, but the larger the copper, and the tinned portion of it, the more solder can be taken up at a time. Carry the solder thus taken up to the place to be soldered, and, if the surfaces have been properly cleaned and fluxed, the solder will adhere to and run over them like water.

When very large surfaces have to be soldered, as in running seams in a tin roof, it is necessary to melt the solder on the top of the bit as that tool is moved along the seam. When soldering heavy lead pipe, it is necessary to feed the solder in the same manner, but for all light work, pick up the solder in the manner described above. If the copper will not readily pick up the solder, rest assured that the tool is not in condition to do good work, and should be sent at once to the tinning brick.

Heavy soldering can be done to advantage with both the soldering copper and the gasoline torch shown by Fig. 2 in the brazing chapter. For jobbing, or for small work, the copper may easily be heated by one of these convenient sources of heat. All that is necessary is to place the tool so that the flame will strike against the copper bit, which may be merely balanced on top of the torch, upon lugs made for that purpose on the torches of the most recent make. For heavy soldering (occasional work), especially where large pieces are to be united, place the torch, with the copper on top, so that the flame will impringe upon the work after it has passed the copper bit. Then, after the copper has been sufficiently heated, the flame may be forced directly against the work to be soldered, the torch being held in one hand, the copper in the other, and the two worked in conjunction. This method permits of a pretty heavy job being done with a light soldering bit. Heat can be put into the copper as well as into the work, while the soldering operation is being carried on.

Again, the work may be heated in the gasoline flame, then tinned with the copper. The entire surfaces to be covered with solder being given a perfect coating of solder, the requisite flux and the hot tinned copper being used for this purpose. After this, the parts of the work may be laid together, heated in the gas flame until the tinning solder melts, then pressed together and the necessary additions of solder, smoothing and otherwise placing the solder, being done with the copper.

Another method of soldering which is frequently used in the machine shop, is known as "sweating." Perhaps two pieces of brass have to be fastened together so as to leave an invisible joint. The workman will fit the pieces as perfectly as possible, then he will wet the parts to come in contact, with soldering fluid, and place the parts together with a sheet of tin-foil between. The pieces are then pressed together and wired or otherwise held fast and heated until the tin-foil melts. After being allowed to cool, the pieces will be found fastened together so nicely that the joint is imperceptible to the eye if good fitting has been done.

Another process, also sometimes called "sweating," consists of tinning separately the parts to be united, after which they are placed in contact with each other and firmly held in position while being heated. After fusion of the solder, the object has its several pieces again brought as closely into contact as possible, either by tapping with a hammer, squeezing in a vise, by pressing together by hand, or by any means possible. Then, the work is left to cool, the superfluous solder removed, and a perfect solder joint is the result provided the manipulations have all been properly carried out. The method last described is commonly used in the machine shop for uniting for use during turning or planing processes, the parts of a ring or bushing which must be in two or more pieces after completion. The several parts are fitted together, sweated into a continuous ring and then machined, after which they are heated, whereupon they fall apart as soon as the solder melts. The solder is removed, by wiping the hot surfaces with a piece of soft cloth and then taking off the balance of the solder which is in the shape of a thin film, with a scraper.—Not the tool shown by Fig. 14, but a flat scraper as used by machinists on flat work where great truth of surface is required.

There are several special operations in soldering, where special work has to be done, and, in every instance, the specials are only adaptations of the ordinary process of soldering, to suit the particular work to be done. For instance: When a number of small or very small parts have to be soldered together in such a manner that the soldering of one would cause the others to become unsoldered, it is customary to hold each and every piece by means of clips and screws, or by means of clamps or weights. For some kinds of work, something very different may be required to hold all the pieces, and, in some cases, it is necessary to put the parts in place one by one, and hold them there by means of calcined plaster, applied in the shape of cream. Each part is held in position until the plaster sets, after which they each will stay in place until the solder can be applied.

For small work, which has to be thus held in place, the soldering copper is frequently too large to get into the small corners between the several parts, and a good deal of trouble is frequently met with in getting the solder properly distributed. For work of this kind, the blow-pipe is the most desirable tool. The blow-torch may be substituted for the blow-pipe if desired, but the former tool enables the heat to be localized better than with the torch. In either case, apply the heat until the solder flows readily, then with a short bit of copper wire, fastened to the end of an iron wire handle, the solder may readily be made to flow where it is needed.

If the bit of thick copper wire on the end of an iron wire handle is not at hand, a piece of copper wire may be used with good results to poke the solder around into the joints, but the trouble with the solid copper wire is that copper is a much better conductor of heat than the iron and the solid copper wire used as a small soldering bit, speedily becomes hot along its entire length and in so doing takes so much heat away from the business end of the tool that it will not continue to melt the solder.

The value of a soldering job frequently depends upon the use of a proper soldering fluid, and the stability of the soldered joint often depends largely thereupon. When acid is used there is little possibility that the joint will be permanent, unless means are taken for removing the excess of acid. However, this matter is much of a puzzle to some very advanced engineers, some acid soldered joints lasting apparently as long as those soldered without the use of acid, other acid soldered joints coming to pieces very quickly after their making. The electrical people have solved the question of the durability of the acid soldering joint by prohibiting its use entirely in electrical work.

One of the most handy soldering solutions consists of common resin dissolved in alcohol. This preparation makes a sort of varnish, which, when applied to a surface, soon parts with its alcohol, leaving a thin film of resin exactly where it will do the most good in soldering. Some good soldering solutions have borax dissolved in them; others have some salammoniac (muriate of ammonia) among their ingredients. This substance is the natural flux for copper, and, owing to the presence of that metal in brass, it works pretty well in fluxing that alloy for soldering.

The most common method of applying resin in soldering is to powder that material and apply it to the work by means of a swab consisting of a small tin or wooden handle to which a tuft of cotton or a few folds of cloth have been fastened. An ordinary coffee mill is a desirable machine for pulverizing resin, also for borax. In the dry flux salammoniac may be ground up with the resin in almost any proportion from one of salammoniac to one hundred of resin up. In the liquid solution, the proportions may be the same, provided a liquid can be found which will carry both the resin and the salammoniac. A solution of salammoniac and borax, or boracic acid, is much valued by some mechanics as a soldering fluid.

Several ancient receipts for soldering fluids or acids call for "killed spirits of salt." Chemically, the solution is one of muriate of zinc. It may be readily prepared, as follows: Place three parts of hydrochloric (muriatic) acid and one part water in a lead, glass or wooden vessel, then add pieces of zinc as long as any action of the acid upon the zinc, can be seen. Some zinc remaining undissolved in the solution after standing for several hours is proof that no more zinc will be dissolved by the acid. Before declaring the operation completed, the following test should be made to determine that there is sufficient water in the solution, without which the maximum quantity of zinc will not be dissolved by the acid. To make this test, remove a few drops of the solution to a clean vessel and place a bit of clean zinc in the liquid. Add water drop by drop, and observe if any action upon the zinc follows the addition of water to the solution. If such action commences, water should be added to the bulk of the solution until further addition does not have effect upon the zinc. If, however, no action is observed in the test solution, the process may be declared finished, and the main solution should be allowed to settle, after which the clear portion is carefully poured off. The sediment, consisting of zinc oxide and perhaps impurities contained in that metal, is not desirable in a working solution for soldering. True, work can be done with dirty soldering acid or other fluid, but better work can be done with clean solutions, as well as surfaces, and tools,

Special Methods of Soldering.

ELECTRICAL WORK

The various trades and manufactures each demand special methods of soldering and joining imposed by conditions peculiar to their own branches of industry. This holds true to the greatest extent in the electrical arts.

One of the first requirements in any piece of electrical apparatus or machinery is that all joints or connections in the electrical circuit shall be as perfect as possible. Poor connections offer resistance to the electrical current, and the apparatus may sometimes refuse to work or else spark and develop sufficient heat at the fault to seriously damage the apparatus and endanger property by fire risk. A soldered joint is absolutely essential when a good *electrical* connection is desired. Although it is possible to secure a good electrical contact or connection by simply clamping a wire under a screw or a nut, it is often soldered in addition to prevent any possible loosening. Soldering also prevents oxidation of the two surfaces brought into contact with each other.

The most important consideration in work of this sort is the employment of the proper flux. The code of the National Board of Fire Underwriters permits the use of a flux composed of chloride of zinc, alcohol, glycerine, and water. This preparation is easily applied, and remains in place. It permits the solder to flow freely, and is not highly corrosive. The proportions in which the ingredients of this flux may be mixed vary considerably, according to individual taste, but the following will generally be found satisfactory:

Zinc Chloride	5 parts
Alcohol	4 parts
Glycerine	3 parts

Use anhydrous zinc-chloride crystals and dissolve in alcohol. The glycerine is added to make the preparation adhesive. It may be diluted with water if desired. Without the water, the alcohol in the preparation takes fire if the articles to be soldered are heated very hot or a blowpipe is used. Sometimes this is an objection.

However useful this flux may be in soldering various parts and repairing mechanical pieces, its use is prohibitive in soldering wires and conductors which are a part of any electrical instruments such as telephone, telegraph apparatus, etc. There are a great many fluxes on the market put out in the shape of paste and "soldering sticks." None of these, however, are any more suitable for work of the kind just mentioned than the chloride-of-zinc solution.

Some fluxes are of a corrosive nature and *eat* the wires and apparatus after the soldering has been done. In many electrical instruments, such as telephone, telegraph, and measuring apparatus, the wires may be only .005–.003 inch, or even smaller. It can readily be appreciated that the slightest corrosive action in such cases would have a decidedly deleterious effect. Purchasers of this class of apparatus usually specify that it be "rosin-soldered." Although the use of rosin in such cases is the best practice, all manufacturers do not adhere to it, because very often the solder will flow more easily and quickly if some other flux is used, and time and labor may be saved.

Rosin is the best flux for such purposes, and most conscientious manufacturers do not depart from its use. No other suitable substance has been discovered which will serve the purpose of causing the solder to flow and still leave the insulating parts in the state of an insulating quality, after the work is finished.

In the case of large conductors which cannot be well heated by the copper, it is not always possible to obtain good results, and for that reason most electricians employ the flame of an alcohol torch or blowlamp. Likewise, when the wires are large, or in the shape of a heavy cable, rosin is not insisted upon as a flux.

In factories where the work is light and an employé performs the same operation all day long, the soldering-iron is not carried to the work, but the process is reversed. The soldering-iron is held in an inclined position in a clamp, and the pieces are brought up under the soldering-iron. When the work is in the hands of a skilful operator, a single wipe across the surface of the iron is sufficient to complete the job.

In such cases it is usual to employ an electric soldering-iron, kept at a uniform heat by a coil of wire through which a current of electricity passes, contained within the body of the iron itself. Electric irons are very often provided with a stand so arranged that when the iron is laid down on the stand the amount of current is reduced to a degree just sufficient to keep the iron hot. In that way the electric current is economized and the life of the heating-coil lengthened without the inconvenience occasioned were the current to be completely shut off and the iron allowed to possibly become cold.

There are also self-heating soldering-irons on the market which embody a small gasolene torch contained within the bit and a tank for the fuel carried at the other end and composing the handle.

In telephone and similar work it is usual to employ wire which has been tinned or coated with solder in its manufacture. The small clips or terminals used on coils and magnets are usually tinned, and in that event the soldering is conveniently done with solder provided with rosin already in it, and known as a self-fluxing solder, or as "rosin-core."

Self-fluxing solders are obtainable in several varieties. Some are sold in the shape of a seamless tube and another is rolled out of a flat strip. The round solder is more generally used. The flat solder contains a lesser proportion of flux to solder than the round, and is used under conditions where less flux is desired. The greatest advantage of rosin-cored solder lies in its convenience and the fact that, while both the material and labor are also saved, a much neater job is possible and unsightly lumps, which often cause short circuits, are avoided.

Fig. 18 shows how two wires are twisted together preparatory to soldering. In the first part of the illustration the ends of two wires are connected, and in the second the end of one is connected to another so as to form a branch.

When wires of a very fine gauge are to be soldered, it is impossible to use a torch or blowlamp because the excessive heat would melt the wires. A soldering bit or copper in the same case would be very awkward and impossible to bring into proper position, so it is usual

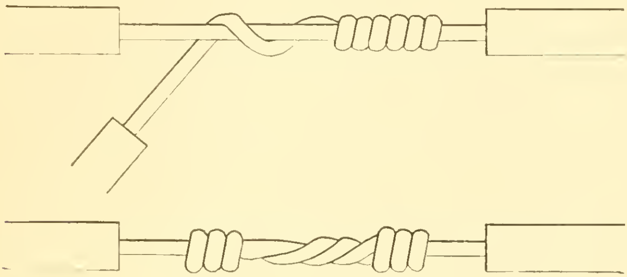


Fig. 16. Wires twisted together.

to employ a small piece of copper wire (about No. 8 B. S. gauge) which has been tinned and set into a handle as a soldering-iron. It may be heated very quickly in the flame of an alcohol lamp.

TIN-PLATE

When tin-plate is new and bright it is possible to solder it without the use of any flux. Rosin is the best flux for the purpose, however. If the tin-plate is old and tarnished it is necessary to use the chloride-of-zinc flux after the metal has been thoroughly cleaned by scraping or rubbing with emery-cloth until the surface is fresh and bright. After the soldering is finished the article should be carefully washed and dried to remove all traces of the zinc chloride and prevent the possible corrosion of the protecting layer of tin.

Soldering.

Tin-plate is one of the easiest substances there is to solder, for the reasons that it is already "tinned" and is thin enough to absorb the heat quickly so that the solder will run very freely.

GALVANIZED IRON AND ZINC

Galvanized iron is iron or low steel covered with a layer of zinc to protect it from the action of time and the elements. Both galvanized iron and sheet zinc are best soldered with a bit, using chloride of zinc as a flux. If the chloride-of-zinc solution is mixed with one-fourth its volume of hydrochloric acid the solder will oftentimes flow more readily, the action of the "free" acid being to dissolve the oxide from the surface of the metal and form more chloride of zinc. The work should be washed after the soldering is finished to remove all traces of the acid.

LEAD

Lead-soldering is usually accomplished with the aid of the soldering-bit or copper. The parts to be joined are scraped clean, but are rubbed with tallow, which serves as the flux in this case, instead of rosin or zinc chloride.

Self-fluxing solder having a core composed of tallow instead of rosin can be procured at most hardware stores. It is made especially for soldering lead, and is particularly desirable for lead-cable repairs and in art and stained-glass work. Most amateur craftsmen who enjoy making decorative lamp-shades, windows, etc., prefer it for that work.

In making joints in lead it is sometimes desirable to employ a method of autogenous soldering called "lead-burning." The result is stronger and cleaner work.

Lead-burning consists in melting the metals and causing the parts to flow together and become joined without the aid of solder. It requires considerably more skill than any other form of brazing or soldering. A long step toward success may be taken by the proper arrangement of the work. It is usual to provide something which may serve as a mold or guide for the melted metal. For example, if two lead sheets are to be united by soldering, they are laid edge to edge on a sheet of some non-heat-conducting substance, such as brick or asbestos. The work in the immediate neighborhood of the joint is carefully scraped so as to remove all oxide or scale which would tend to bind the melted lead and prevent it from flowing freely. The metal at the seam is melted by a very hot bit or the flame from a blowpipe so that there is a uniform flow of lead across the seam. It is sometimes necessary to add more lead to the seam by melting a strip held in the hand.

A flame of some sort is the most satisfactory source of heat for the average lead-burning job, because not only is the heat more uniform, but also more intense, and the lead melts at the desired point before the surrounding metal becomes sufficiently hot to soften.

There are several types of blowpipe for this purpose on the market. Some employ an alcohol flame, while others make use of mixed hydrogen and air. The flame is usually small, sharp-pointed, and very intense.

Lead-burning is absolutely necessary, and is insisted upon in certain classes of work, for instance, in lining tanks with lead for chemical solutions, or for joining the grids and lugs of storage batteries. The presence of even the smallest amount of solder containing a foreign metal such as tin causes a local action to be set up, and the chemicals slowly attack the seam at that point. Most of the large manufacturers of storage cells also make a pair of lead-burning tongs which are of the proper size and shape to fit around the lug of their cells. These can be purchased for repair work, and provide a snug mold, so that all that is necessary is to flow the lead with the flame and allow it to cool.

LEAD PIPES

Where conditions preclude the possibility of cutting a thread, it is sometimes necessary to join an iron pipe to a lead pipe by soldering. In such a case the end of the iron pipe is first carefully scraped and then tinned with the aid of some "sodium solder." Sodium solder is not a necessity, but makes possible a much quicker and easier operation.

Sodium solder is prepared by dropping small pieces of metallic sodium into a ladle full of melted solder. The sodium will melt and become absorbed by the solder with a slight puff of smoke. Most of the prepared solders which are on the market and readily adhere to metals without the aid of a flux contain a certain percentage of sodium. Sodium solder can be used very successfully for tinning, but joints made wholly with it tend to corrode.

After the iron pipe has been scraped and tinned it is an easy operation to solder the lead pipe to it, using tallow as a flux.

When brass fittings are soldered to an iron pipe it is the most desirable to use a blowpipe if possible, because it performs in this case a more satisfactory job than the bit or copper.

The end of the lead pipe is expanded slightly by driving in a turnpin, and then carefully scraped inside. The clean portion is covered with rosin or tallow. The end of the brass fitting is cleaned and tinned, and, after being driven into place, a blowpipe flame directed upon the joint. More heat should be given to the brass than to the lead. The heat should be just sufficient so that the solder will flow freely into the joint, but the pipe itself will not melt. At the instant of complete fusion a quick wipe around the joint with tallow will finish and smooth the job.

The "wiped" joint so commonly employed by plumbers in fitting lead pipes where water pressure must be withstood is an operation requiring skill and practice. The joint is prepared for wiping by first expanding one side so that the other will fit snugly into it. After the metal has been thoroughly cleaned it is smeared with tallow and put in position. "Plumber's" solder is splashed or poured over the joint until the metal adjacent is heated almost to the melting-point, and the solder flows over joint and amalgamates with it. The running solder is immediately caught in a wiping-pad held underneath the joint and worked around the joint to the shape shown in Fig. 19. As the solder becomes cooler it changes to a crystalline and granular state, and is "mushy." A wiping-pad is composed of several thicknesses of heavy duck saturated with tallow.

The portions of the work beyond the joint, where it is desirable that no solder should appear, are usually painted with a mixture of size and lampblack.

The same principle is employed in "wiping" joints or seams in sheet lead. The boundaries are painted or "soiled" with lampblack so that the solder will not adhere to those portions. The area to be covered is scraped clean and rubbed with tallow. The solder may be poured on or melted on from a stick heated with a

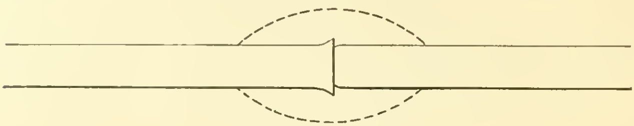


Fig. 17. Wiped joint.

torch or blowpipe. Perhaps the last method is the best. As soon as the work has been heated sufficiently to become plastic, the seam is shaped with a wiping-pad or with a special-shaped piece of wood or asbestos.

ALUMINIUM

Aluminium is the most difficult metal to solder. It was a long time before any satisfactory solder for joining this metal could be discovered, and for a time it was thought impossible.

The aluminium solders now on the market consist of "straight" aluminium solders and "combination" solders. The "straight" solder is used for soldering aluminium to aluminium and the "combination" solder for soldering any metals, copper, brass, etc. (except cast iron), to aluminium.

Parts to be soldered with the straight solder should first be cleaned with gasolene by brushing the surface to be soldered with a steel file brush to remove all grease.

Heat the parts to be soldered with the flame of a blowpipe until the solder begins to melt upon them. Then brush the melted solder well into the metal. If any dross forms on the surface, brush or scrape it off well. Each part should be tinned separately and then pressed together and soldered.

To use combination solder, "tin" the metal to be soldered to the aluminium with some of the "combination," using any good flux for the purpose. After cooling remove all traces of the flux and prepare the aluminium piece with some of the "straight" solder, as described above. The parts may then be joined with some of the "straight" solder without the use of any flux.

The "combination" solder is merely for tinning purposes, while the "straight" solder is for the actual soldering.

Solders and Fluxes

The metallic mixtures used for joining other metals with the aid of heat are called solders. The variety and number is considerable, but may be divided into two general classes—namely, "hard" and "soft" solders.

Soft solders are alloys of tin, lead, etc., which melt at comparatively low temperatures and are usually employed in conjunction with a copper bit or soldering-iron. Hard solders are alloys of silver, copper, zinc, etc., which melt at very much higher temperatures. A torch or blowpipe must be used to obtain sufficient heat to melt hard solders.

SOFT SOLDERS

Soft solder finds its principal use in ordinary sheet-metal or tinsmiths' work, in which tin-plate, copper, brass, and zinc are the materials most frequently requiring to be soldered.

Tin and lead in varying combination are the principal constituents of soft solders. They have different properties and melting-points, according to the proportion between the two metals.

The manufacture of solder is very simple. If the alloys are to be mixed in small quantities, a sensitive pair of scales is required to weigh the constituents accurately. When made in quantity a slight variation in the proportion is not so noticeable.

Lead has a higher melting-point than tin, and should naturally be melted first if it were not for the fact that

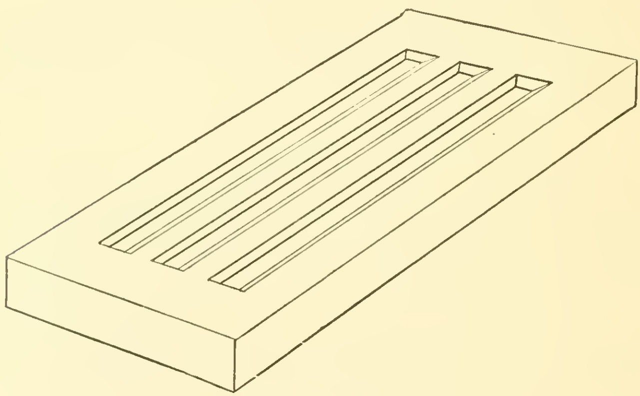


Fig. 18. Mold.

it easily oxidizes when melted alone. Melt the tin first and the lead afterward, adding it in small lumps until it has all been melted. Stir the mixture constantly with a wooden paddle until the metals are thoroughly mixed. If not carefully stirred some parts of the solder will contain the metals in different proportions from the other parts, and will have a different fusing-point.

Solder may be molded in the form of sticks by casting in an iron mold arranged as in Fig. 15. The sides are slightly wider at the top than at the bottom, so that the rods can easily be removed.

It is preferable to prepare solder in a clay pot or Hessian crucible. If an iron pot is used, solder will take up a trace of the iron and become harder and more brittle than if the clay pot were used.

In some cases it is desirable to add a little bismuth on account of the property which the latter possesses of materially lowering the fusing-point of any alloy of which it is a part. While all solders have a very low fusing-point, they also have the disadvantage of being brittle and of possessing little cementing power.

In preparing any solder containing bismuth, the lead and tin should be melted and mixed first. The mixture is then removed from the fire and the bismuth added in powdered form, stirring all the while with a wooden paddle.

The composition of some of the most common forms of solder is given below:

No. 1.—Plumbers' solder, also called "half-and-half." Used for wiped joints, etc.: tin, 1 part; lead, 1 part. Melts at 370° F.

No. 2.—Ordinary solder for general use with a soldering-bit: tin, 5 parts; lead, 3 parts. Melts at 350° F.

No. 3.—Solder for blowpipe: tin, 2 parts; lead, 1 part. Melts at 340° F.

No. 4.—Solder for blowpipe: tin, 2 parts; lead, 1 part; to each pound of the above add one-half ounce of bismuth. Melts at 310° F.

No. 5.—Easy-running blowpipe solder: tin, 2 parts; lead, 1 part; bismuth, 1 part. Melts at 245° F.

No. 6.—Sodium solder: add a few small pieces of solder about as large as grains of wheat to a ladleful of molten No. 1 or No. 2 solder.

No. 7.—In some cases a solder having a very low melting-point for pewter, etc., is desirable. In that case the following alloy will be found suitable: lead, 2 parts; tin, 1 part; bismuth, 2 parts. Melts at 236° F.

No. 8.—Wood's metal. This is interesting because it melts below the boiling-point of water. It is useful for soldering detector minerals in wireless telegraphy, which are easily damaged by excessive heat: cadmium, 1 part; tin, 2 parts; lead, 4 parts; bismuth, 7 parts.

Whenever it is desirable to make solders which are especially adapted to one particular use or metal the following table will be found very useful:

SOFT SOLDERS

Metal to be Soldered	Percentage of		Flux
	Tin	Lead	
Lead	33	67	Tallow or Rosin
Iron and Steel	50	50	Chloride of Ammonia
Zinc	55	45	Hydrochloric Acid
Galvanized Iron or Steel	58	42	Hydrochloric Acid
Tinned Steel or Iron	64	36	Chloride of Zinc or Rosin
Brass or Gun-metal	66	34	Chloride of Zinc, Rosin, or Chloride of Ammonia
Gold and Silver	67	33	Chloride of Zinc
Block Tin	99	1	Chloride of Zinc

Metal to be Soldered	Tin	Zinc	Aluminium	Phosphor Tin	Flux
Aluminium......	70	25	3	2	Stearine
		Lead	Bismuth		
Bismuth	33	33	33	..	Chloride of Zinc
Pewter..........	25	25	50	..	Gallipole

HARD SOLDERS

The fusion-point of hard solders is usually so high that they cannot be melted with an iron, but must be raised to a red heat with the aid of a blast or a blowlamp. The great variety of hard solders is made necessary by the differences in the nature of the various materials which may require soldering. Not all of the numerous formulas for hard solders are perfectly reliable, but those given below have been carefully tested and found reliable.

Pure copper, where its color is no objection, is often employed in the form of thin strips for soldering cast iron, copper, wrought iron, and steel.

The best and most usual form of hard solder for soldering copper is composed of five parts of copper and one of lead. A very small percentage of tin may sometimes be added with good results.

Brass solders are used to solder brass, bronze, copper, iron, and steel. These alloys are composed of brass and copper in varying proportions. The fusing-point is raised as the amount of copper is increased. The alloy becomes more brittle as the proportion of zinc becomes greater. This objectionable property may be somewhat modified by adding a little tin. Too much tin, however, will cause the solder to become brittle again.

The following four formulas make excellent hard solders for all purposes where a high melting-point is required:

VERY HARD YELLOW SOLDERS

No. 1.—Copper, 58 parts; zinc, 42 parts.

No. 2.—Sheet brass, 85.42 parts; zinc, 13.58 parts.

No. 3.—Brass, 7 parts, zinc, 1 part.

No. 4.—Copper, 53.30 parts; zinc, 43.10 parts; tin, 1.30 parts; lead, .30 part.

The hardest solders are given first. The following four have lower melting-points than those above, and are more suitable where it is desired to solder brass alone.

No. 5.—Brass, 66.66 parts; zinc, 33.34 parts.

No. 6.—Brass, 50 parts; zinc, 50 parts.

No. 7.—Brass, 12 parts; zinc, 4 to 7 parts; tin, 1 part.

No. 8.—Copper, 44 parts; zinc, 49 parts; tin, 3.20 parts; lead, 1.20 parts.

The proper composition of hard solders for specific purposes is shown in the following table:

Metal to be Soldered	Copper	Zinc	Silver	Gold	Flux
Copper	50	50	..	..	Borax
Brass, Soft	22	78	..	..	Borax
Brass, Hard	45	55	..	..	Borax
Cast Iron	55	45	..	..	Cuprous Oxide
Iron and Steel	64	36	..	..	Borax
Gold	22	2	11	65	Borax
Silver	20	10	..	70	Borax

GERMAN-SILVER SOLDERS

German silver is a very hard alloy, containing nickel, and requires a solder of somewhat similar nature.

German-silver solders possess considerable strength, and are often used for soldering steel. The color is very similar to that of steel.

Hard German-silver solders contain a large proportion of nickel and are very strong. They require a very high heat for melting, and usually cannot be fused without the aid of a bellows or blast.

In preparing German-silver solders, the copper is melted first, and then the zinc and nickel added simultaneously.

HARD GERMAN-SILVER SOLDERS (also called steel solders)

No. 1.—Copper, 35 parts; zinc, 56.5 parts; nickel, 9.5 parts.

No. 2.—Copper, 38 parts; zinc, 50 parts; nickel, 12 parts.

SOFT GERMAN-SILVER SOLDERS

No. 3.—Copper, 4.5 parts; zinc, 7 parts; nickel, 1 part.

No. 4.—Copper, 35 parts; zinc, 56.5 parts; nickel, 8.5 parts.

In soldering German-silver articles the solder is usually applied in the form of a powder or in very small pieces. The solder may be powdered in a mortar if taken from the fire at the right temperature, when it is brittle. This operation is a somewhat difficult one, and so the usual and perhaps the best plan is to cast it in the form of a bar or cylinder, and then place the latter in a turning-lathe and adjust the tool so that fine shavings are cut off. The shavings are then heated until they become brittle, at which stage they are easily pulverized in a mortar.

SILVER SOLDERS

Silver solders are not, as might be inferred from the name, employed only for the purpose of joining silver; but because of their great strength and resistance are used for many other metals. Like all other solders, they may be divided into the two groups, "hard" and "soft."

SILVER SOLDERS FOR SOLDERING SILVERWARE

Hard	*Soft*
No. 1	No. 4
Copper, 1 part;	Silver, 2 parts;
Silver, 4 parts.	Brass, 1 part.
No. 2	No. 5
Copper, 1 part;	Silver, 3 parts;
Silver, 20 parts;	Copper, 2 parts;
Brass, 9 parts.	Zinc, 1 part.
No. 3	No. 6
Copper, 2 parts;	Silver, 10 parts;
Silver, 28 parts;	Brass, 10 parts;
Brass, 10 parts.	Tin, 1 part.

SILVER SOLDERS FOR IRON, CAST IRON, STEEL, AND COPPER

No. 1.—Silver, 10 parts; copper, 10 parts.

No. 2.—Silver, 20 parts; copper, 30 parts; zinc, 10 parts.

Silver solders are usually employed in the shape of wire, narrow strips, or filings.

FLUXES

No one flux can be assigned to any one metal as being peculiarly adapted or fitted to that metal for all purposes. The nature of the solder used often determines the flux.

Directions have already been given for preparing chloride of zinc for soft soldering.

A good flux for hard soldering may be made by heating three parts of ordinary crystal borax and one part of boracic acid together over a gentle fire until the whole melts together into a clear, thick sirup.

The flux is used in this condition and is not dried. It will remain a long time without drying and is easily applied to the surface to be soldered, to which it firmly adheres. This flux also possesses the further advantages of being easily removed after soldering and not swelling when heated.

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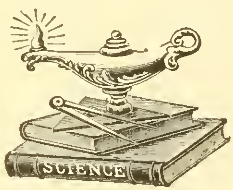

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